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U.S. GEOLOGICAL SURVEY

Selected Micrometeorological and Soil-Moisture Data at Amargosa Desert Research Site in Nye County Near Beatty, Nevada, 1998–2000

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By Michael J. Johnson, Charles J. Mayers, and Brian J. Andraski

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2002

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES G. GROAT, Director

For additional information
contact:

District Chief
U.S. Geological Survey
333 West Nye Lane, Room 203
Carson City, NV 89706–0866

email: GS-W-NVpublic-info@usgs.gov

URL: http://nevada.usgs.gov

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
centimeters (cm)	0.3937	inch
millimeter (mm)	0.03937	inch
micrometer (µm)	0.000039	inch
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
	Volume	
liter (L)	0.2642	gallon
	Volume per unit time (includes flow)	
meter per second (m/s)	3.281	foot per second
millimeter per hour (mm/h)	0.03937	inch per hour
	Pressure	
kilopascal (kPa)	0.1450	pound-force per square inch
	Radioactivity	
becquerel per liter (Bq/L)	27.027	picocurie per liter
Watts per square meter (W/m^2)	0.005290	British Thermal Unit per square foot per minute

Temperature: Degrees Celsius (^{O}C) can be converted to degrees Fahrenheit (^{O}F) by using the formula $^{O}F = [1.8\ (^{O}C)] + 32$. Degrees Fahrenheit can be converted to degrees Celsius by using the formula $^{O}C = 0.556\ (^{O}F - 32)$. Degrees Kelvin ($^{O}K$) can be converted to degrees Fahrenheit (^{O}F) by using the formula $^{O}F = [1.8\ (^{O}K - 273)] + 32$. Degrees Fahrenheit can be converted to degrees Kelvin by using the formula $^{O}K = [0.556\ (^{O}F - 32)] + 273$.

Radiation: A unit of activity is a Curie (Ci), which is equivalent to 37×10^{10} disintegrations per second (dps); the standard disintegration rate of 1 gram of Radium. In International Units a Bequerel (Bq) is equivalent to 1 disintegration per second (dps). Thus, 10 milliCuries (mCi) equals 370 megaBequerels (MBq).

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called “Sea-Level Datum of 1929”), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

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Selected Micrometeorological and Soil-Moisture Data at Amargosa Desert Research Site in Nye County Near Beatty, Nevada, 1998–2000

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ABSTRACT

Selected micrometeorological and soil-moisture data were collected at the Amargosa Desert Research Site adjacent to a low-level radioactive waste and hazardous chemical waste facility near Beatty, Nev., 1998–2000. Data were collected in support of ongoing research studies to improve the understanding of hydrologic and contaminant-transport processes in arid environments.

Micrometeorological data include precipitation, air temperature, solar radiation, net radiation, relative humidity, ambient vapor pressure, wind speed and direction, barometric pressure, soil temperature, and soil-heat flux. All micrometeorological data were collected using a 10-second sampling interval by data loggers that output daily mean, maximum, and minimum values, and hourly mean values. For precipitation, data output consisted of daily, hourly, and 5-minute totals. Soil-moisture data included periodic measurements of soil-water content at nine neutron-probe access tubes with measurable depths ranging from 5.25 to 29.75 meters.

The computer data files included in this report contain the complete micrometeorological and soil-moisture data sets. The computer data consists of seven files with about 14 megabytes of information. The seven files are in tabular format: (1) one file lists daily mean, maximum, and minimum micrometeorological data and daily total precipitation; (2) three files list hourly mean micrometeorological data and hourly precipitation for each year (1998–2000); (3) one file lists 5-minute precipitation data; (4) one file lists mean soil-water content by date and depth at four experimental sites; and (5) one file lists soil-water content by date and depth for each neutron-probe access tube.

This report highlights selected data contained in the computer data files using figures, tables, and brief discussions. Instrumentation used for data collection also is described. Water-content profiles are shown to demonstrate variability of water content with depth. Time-series data are plotted to illustrate temporal variations in micrometeorological and soil-water content data. Substantial precipitation at the end of an El Niño cycle in early 1998 resulted in measurable water penetration to a depth of 1.25 meters at one of the four experimental soil-monitoring sites.

INTRODUCTION

Research at the Amargosa Desert Research Site (ADRS) is intended to develop a fundamental understanding of hydrologic and contaminant-transport processes in arid regions. Research objectives are to advance the state of hydrologic science and to provide scientific information for those making decisions concerning waste isolation and water management in desert environments. Information on the ADRS is available on the internet at: <http://nevada.usgs.gov/adrs/>.

In support of ongoing research, micrometeorological and soil-moisture data were collected at the ADRS adjacent to a low-level radioactive and hazardous chemical waste facility near Beatty, Nev. The waste facility has been used for the burial of low-level radioactive waste from 1962 through 1992 and hazardous-chemical waste from 1970 to present. The ADRS was incorporated into the U.S. Geological Survey (USGS) Toxic Substances Hydrology Program in 1997. Investigations at the ADRS began in 1983 and have produced long-term benchmark data on hydrologic characteristics and soil-water movement for undisturbed conditions and for simulated waste-disposal conditions in arid environments (Andraski and Stonestrom, 1999).

This report includes selected micrometeorological data and soil-moisture data collected for the period 1998–2000. Soil-moisture data collected during November and December 1997 also are included. Instrumentation used to collect the data is described. This report is the seventh in a series of meteorological reports published for this site (Wood and Fischer, 1991, 1992; Wood and others, 1992; Wood and Andraski, 1992, 1995; Wood, 1996). These previous reports include meteorological data collected during a 7-year period (1986–92). Meteorological data were not reported for a 5-year period (1993–97) due to funding constraints.

The micrometeorological data collected for a 3-year period (1998–2000) include precipitation, air temperature, solar radiation, relative humidity, ambient vapor pressure, wind speed and direction, and barometric pressure. In addition, net radiation data collection started in July 1998, and soil temperature and soil-heat-flux data collection started in September 1999. The soil-moisture data were collected periodically during the 3-year period and consist of volumetric soil-water content measurements made using a neutron probe.

Computer data files contain the complete micrometeorological (apps. A and B) and soil-moisture (app. C) data sets summarized in this report. These data consist of seven tabular files with about 14 megabytes of information. The tabular, computer data files (hereafter referred to as data tables) include: (1) one file of daily mean, maximum, and minimum micrometeorological data and daily total precipitation; (2) three files of hourly mean micrometeorological data and hourly precipitation for each year (1998–2000); (3) one file of 5-minute precipitation data; (4) one file of mean soil-water content by date and depth for four experimental sites; and (5) one file of soil-water content by time and depth for each neutron-probe access tube.

SITE DESCRIPTION

The ADRS is near a waste-burial facility about 17 km south of Beatty, Nev., and 20 km east of Death Valley, Calif. (fig. 1*A*). The ADRS is in the Mojave Desert ecosystem, one of the most arid regions in the United States. Vegetation in the area is sparse; creosote bush [*Larrea tridentata*], an evergreen shrub, is the dominant species. The Amargosa Desert is in the Basin and Range physiographic province. Sediments beneath the study area and the waste-burial facility primarily are basin fill consisting of unconsolidated alluvial fan, fluvial, and marsh deposits (Clebsch, 1968). The basin fill is estimated to be more than 170 m thick (Nichols, 1987, p. 8). Depth to the water table ranges from 85 to 115 m (Fischer, 1992, p. 12).

Other studies at the ADRS facility have been established to support research of flow and transport processes within the thick unsaturated zone above the water table. The research site has two fenced areas; one enclosing an instrument shaft (figs. 1*B* and 2; Fischer, 1992), and the other enclosing simulated waste trenches (figs. 1*B* and 3; Andraski, 1990). A weather station with two precipitation gages and three neutron-probe access tubes are within the instrument shaft area (fig. 2). These instruments are used for monitoring soil-water content in a vegetated, native-soil profile. Six neutron-probe access tubes and a single precipitation gage are within the simulated waste trenches (fig. 3). The tubes are used to measure soil-water content under nonvegetated, simulated waste-trench conditions and under devegetated, but undisturbed native-soil conditions. Ground-water levels have been measured periodically since 1987 at well MR-3 (fig. 1*B*). Deep test holes (UZB-1, -2, -3; fig. 1*B*) have been used for measurements of temperature, water potential, and air pressure; and for collection of soil-gas samples throughout the thick unsaturated zone (Prudic and Striegl, 1995; Prudic and others, 1999; Andraski and Prudic, 1997). Not shown in the figures is an array of soil-gas sampling tubes that are used for periodic collection and analysis of the chemical composition of unsaturated-zone air to a depth of about 1.5 m (Healy and others, 1999; Striegl and others, 1998). Similarly, numerous plant-sampling sites have been established to evaluate soil-plant-atmosphere interactions and ultimately to determine how those interactions affect the potential release of contaminants.

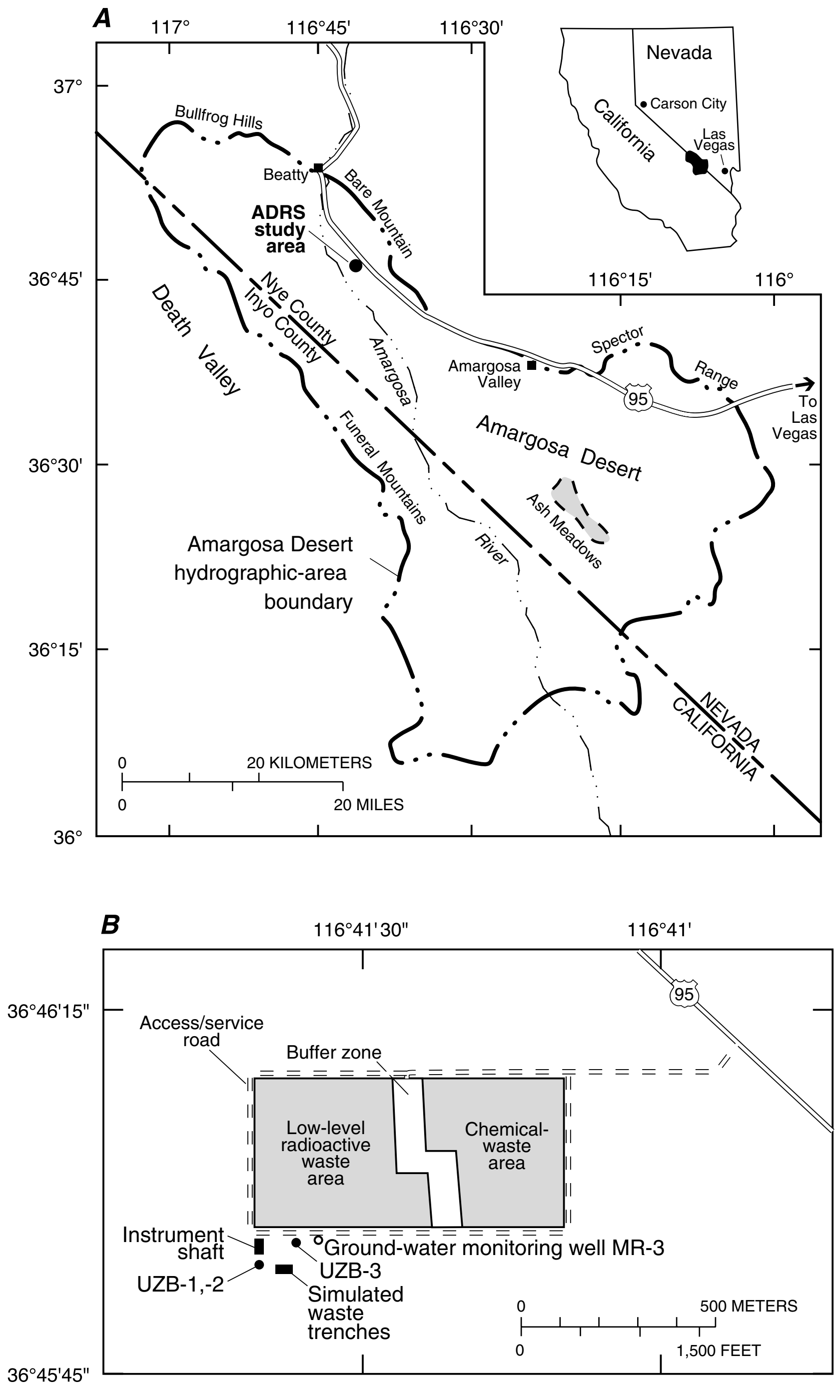

Figure 1. Location of (*A*) Amargosa Desert Research Site near Beatty, Nev., and (*B*) instrument shaft and simulated waste trenches adjacent to waste-disposal facility.

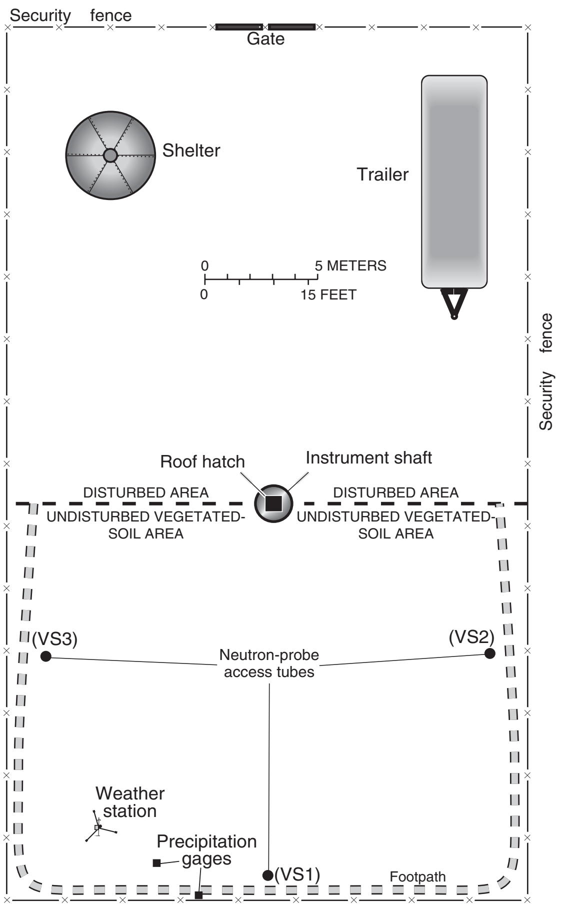

Figure 2. Fenced area of instrument shaft showing location of weather station, neutron-probe access tubes, and precipitation gages at Amargosa Desert Research Site near Beatty, Nev.

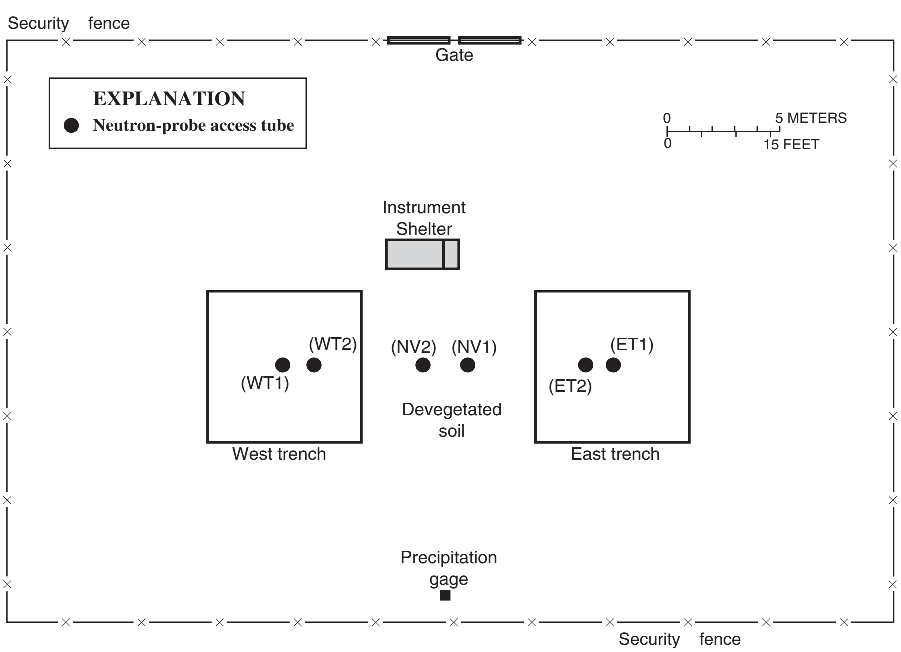

Figure 3. Fenced area of simulated waste trenches showing location of neutron-probe access tubes and precipitation gage at Amargosa Desert Research Site near Beatty, Nev.

MICROMETEOROLOGICAL INSTRUMENTATION

Micrometeorological sensors consisting of a tipping-bucket rain gage, an air-temperature and relative-humidity probe, a barometric-pressure sensor, a pyranometer, and an anemometer with wind vane were installed in December 1997. A radiometer was installed at the site in July 1998. Soil-temperature probes and two soil-heat-flux plates were installed in September 1999. Two accumulating rain gages periodically were read after storm events to check the data values obtained by the tipping-bucket rain gage.

Data from all the sensors except the net radiometer were recorded using a Campbell Scientific, Inc. (CSI), 23X data logger[1] with a 10-second sampling interval. The logger was programmed to output data in three formats: daily output of mean, maximum, and minimum values (but totals for precipitation); hourly output of mean values (but totals for precipitation); and 5-minute totals for precipitation. The data for the net radiometer were recorded using a CSI 21X data logger with a 10-second sampling interval and programmed to output hourly mean values. Both data loggers are interfaced to a telephone modem permitting automated communication and data retrieval using an off-site computer. The data loggers reference Pacific Standard Time (PST) throughout the year.

The weather station used a CSI 10 tripod to mount the temperature-relative-humidity sensor, pyranometer, and anemometer with wind vane. Mounted on the tripod above the ground were the air temperature-relative humidity sensor at 1.5 m; the solar-radiation sensor at 3 m; and the anemometer with wind vane mounted on a horizontal arm with the center of the wind cups at 3 m. The barometric-pressure sensor was mounted 1 m above the ground and housed with the CSI 23X data logger in a shelter about 30 m from the tripod (fig. 2). The net radiometer was mounted 1.5 m above the ground and about 10 m from the tripod within the undisturbed vegetated area. The precipitation tipping-bucket rain gage was installed on its own mount about 5 m from the tripod at a height of 1 m. Adjacent to the tipping-bucket rain gage was an accumulating plastic rain gage made by Tru-Chek mounted at a height of 1 m along the south fence of the instrument shaft area (fig. 2), and a second Tru-Chek rain gage was at the south end of the waste-trench area (fig. 3). Two soil-heat-flux plates were buried in the soil at a depth of 0.08 m about 2 m from the weather-station tripod. Between the flux plates and the soil surface, the averaging soil-temperature probes were buried at depths of 0.02 m and 0.06 m.

The accuracy of the data is dependent on the sensors being used. The tipping-bucket rain gage is a WeatherMeasure model P-501 with a resolution of 0.25 mm representing one tip of the bucket, and an accuracy of 0.5 percent at 12.7 mm/h. The air temperature-relative humidity probe is a Vaisala HMP35C from CSI with a temperature accuracy of $\pm$ 0.4°C over a range from –24 to 48°C, and with a relative humidity accuracy of $\pm$ 2 percent within the range from 0 to 90 percent and $\pm$ 3 percent within the range from 90 to 100 percent. The Vaisala probe was mounted inside a 12-plate gill radiation shield. Solar radiation is measured with a LI-COR LI200X silicon pyranometer calibrated against an Eppley Precision Spectral Pyranometer, which has a maximum error of $\pm$ 5 percent. The net radiometer was a Radiation and Energy Balance Systems (REBS) Q7.1 net radiometer, which has a spectral response from 0.25 to 60 µm with a nominal resistance of 4 ohms. Wind speed and direction was measured by a Met One 034A-L Windset with a wind speed accuracy of $\pm$ 0.12 m/s and a threshold of 0.28 m/s, and with a wind direction accuracy of $\pm$ 4 degrees. The barometric-pressure sensor is a CSI SBP270 with a pressure range from 800 to 1,100 mbar and an accuracy of $\pm$ 0.2 mbar. Soil temperature was measured with a TCAV-L averaging soil temperature probe manufactured by CSI with two junctions at two depths and constructed with Type-E thermocouple (chromel-constantan) wire. The four thermocouples and associated reference temperature define an averaged soil temperature with a typical uncertainty of 0.5°C, but the uncertainty can be as high as 1.6°C. The soil-heat flux was measured with two REBS HFT3 plates with a nominal resistance of 2 ohms and a thermal conductivity of 1.00 W/m/°K. The soil-heat-flux plates have an error of about $\pm$ 5 percent.

SOIL-MOISTURE INSTRUMENTATION

Measurements of soil-water content were collected from neutron-probe access tubes using a CPN 503 Hydroprobe manufactured by Campbell Pacific

[1] Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Nuclear International, Inc. The probe uses a 50 mCi Americum-241:Beryllium neutron source; or in System International units, a 1,850 mBq source. The fast neutrons propagate through the soil, collide with hydrogen atoms in soil water, become thermalized or slowed, and are then reflected back. The reflected slow neutrons are detected in the tube of the probe and the surface electronic sensor counts each event. Soil-water content is proportional to the number of neutron reflections counted. Counts were accumulated over a period of 30 seconds. Because the neutron source and its detector tube can vary in radiation-flux emissions and detections with time, count ratios are used to normalize the field counts for a given set of measurements. Count ratios are calculated by dividing the field counts by standard counts obtained while the neutron probe is within its shield above the ground.

Access tubes at both the vegetated-soil profile (tubes VS1, VS2, and VS3; fig. 2) and the devegetated-soil profile (tubes NV1 and NV2; fig. 3) were large-steel tubes with a 140-mm outside diameter and a 6.4-mm wall thickness. These access tubes were installed at the vegetated-soil site (July 1988) and the devegetated-soil site (September 1988) using a pneumatically driven downhole-hammer system (Abeele, 1987). Access tubes at the two simulated waste trenches (tubes ET1, ET2, WT1, and WT2; fig. 3) were small-steel tubes with a 51-mm outside diameter and a 3.0-mm wall thickness. These access tubes were installed during trench construction (September 1987) with tubes placed in holes that were hand-augered below the trench floor prior to backfilling (Andraski, 1996). Three access tubes (tubes VS1, VS2, and VS3; fig. 2) were used at the vegetated-soil profile with measurable neutron probe depths of 13.75 m, 29.75 m, and 13.75 m, respectively. Two access tubes were used at each of the other sites (fig. 3) with measurable neutron probe depths of about 5.25 m.

Neutron counts were obtained over a period of 30 seconds at each depth. At the vegetated-soil profile (within the fenced shaft area, fig. 2), single readings were obtained at each depth, with readings typically obtained at intervals of every 0.25 m to a depth of 10.75 m and then 0.5 m below that depth. At the devegetated-soil profile and the two trenches (within the fenced simulated trench area, fig. 3) two readings were obtained at each depth, with readings typically obtained at intervals of 0.25 m.

Using count ratios, calibration equations were developed that had coefficients of determination greater than 0.96 (Andraski, 1997, p. 1904). The standard error of estimate for small-diameter tubes ranged from 0.017 m^3/m^3 for measurements at the 15 m depth to 0.012 m^3/m^3 for measurements at depths greater then 15 m. For large-diameter tubes the standard error of estimate was less than 0.009 m^3/m^3 at all depths.

SELECTED MICROMETEOROLOGICAL DATA

Because of the length of tables 3–5, which summarizes selected micrometeorological data collected at the ADRS facility for 1998, 1999, and 2000, they are at the back of the report following the Basic Data section.

Precipitation

Daily total precipitation is listed in table 1, and monthly total precipitation is shown in figure 4. Complete data for precipitation totals by daily, hourly, and 5-minute periods are in appendices A and B (tables A1–A4 and B1). The tipping-bucket rain gage malfunctioned in November 2000; thus, the daily precipitation data are based on waste-facility records (L.E. Sanders, U.S. Ecology, Inc., written commun., 2001).

Total annual precipitation measured 194.4 mm in 1998, 68.4 mm in 1999, and 91.7 mm in 2000 (table 1). Based on a combination of waste-facility and ADRS precipitation records for the 20-year period (1981–2000), annual precipitation averaged 108 mm. Precipitation during 1998 was about 180 percent of the 20-year annual average and corresponded with the end of an El Niño cycle. Precipitation during 1999 and 2000 was about 63 and 85 percent, respectively, of the long-term average. Winter frontal systems typically account for 70 percent of the ADRS precipitation (Andraski and Stonestrom, 1999, p. 459), whereas summer storms typically account for 30 percent of the precipitation. In the Amargosa Desert the predominant winter precipitation comes from regional winter frontal systems moving in from the west coast. However this precipitation is reduced and variable within the desert, due to the rain shadow effect of the Sierra Nevada mountains, which similarly shadow Death Valley to the west of the Amargosa Desert. Summer precipitation is even more variable, coming mainly from localized convective storms. Summer storm generation is dependent on water vapor transported into the area by southwesterly winds bringing water vapor principally from subtropi-

Table 1. Daily total precipitation at Amargosa Desert Research Site near Beatty, Nev., 1998–2000

[Values are in millimeters. All unlisted dates had no precipitation]

Date	Julian day	Total precipitation	Date	Julian day	Total precipitation
01/04/1998	4	0.25	01/25/1999	25	14.90
01/09/1998	9	.25	01/26/1999	26	5.56
01/10/1998	10	.25	02/09/1999	40	1.26
01/29/1998	29	.51	04/03/1999	93	.51
02/02/1998	33	1.77	04/06/1999	96	5.05
02/03/1998	34	14.64	04/07/1999	97	2.53
02/04/1998	35	4.80	04/08/1999	98	.51
02/06/1998	37	3.79	04/12/1999	102	2.02
02/07/1998	38	3.28	04/23/1999	113	.51
02/08/1998	39	.76	04/24/1999	114	2.78
02/14/1998	45	14.14	04/29/1999	119	2.02
02/17/1998	48	12.12	04/30/1999	120	1.26
02/19/1998	50	2.53	05/24/1999	144	.25
02/20/1998	51	.76	05/27/1999	147	2.78
02/23/1998	54	19.69	07/09/1999	190	4.29
02/24/1998	55	3.54	07/13/1999	194	1.26
03/05/1998	64	.25	07/14/1999	195	4.29
03/06/1998	65	1.01	07/15/1999	196	1.01
03/13/1998	72	7.83	08/10/1999	222	1.26
03/16/1998	75	7.32	09/17/1999	260	13.13
03/17/1998	76	.25	09/18/1999	261	1.26
03/25/1998	84	6.31	01/17/2000	17	1.26
03/26/1998	85	14.14	01/25/2000	25	.51
03/28/1998	87	2.78	01/26/2000	26	1.26
03/29/1998	88	.25	02/10/2000	41	9.59
04/01/1998	91	2.27	02/12/2000	43	2.53
04/12/1998	102	.76	02/16/2000	47	3.28
04/25/1998	115	4.29	02/20/2000	51	5.56
05/05/1998	125	5.56	02/21/2000	52	5.81
05/07/1998	127	1.77	02/23/2000	54	8.08
05/12/1998	132	4.80	02/28/2000	59	2.78
05/13/1998	133	2.02	02/29/2000	60	5.30
06/03/1998	154	3.28	03/05/2000	65	5.81
06/08/1998	159	.51	03/08/2000	68	5.30
06/09/1998	160	.51	04/14/2000	105	1.52
06/10/1998	161	.25	04/17/2000	108	3.79
06/11/1998	162	1.26	08/28/2000	241	2.02
06/12/1998	163	9.85	08/29/2000	242	8.59
07/21/1998	202	11.87	08/30/2000	243	5.81
08/13/1998	225	.76	08/31/2000	244	3.79
08/30/1998	242	7.83	09/08/2000	252	.51
08/31/1998	243	.76	10/11/2000	285	.25
09/04/1998	247	9.59	10/23/2000	297	.51
09/06/1998	249	.51	10/29/2000	303	1.01
09/08/1998	251	.51	10/30/2000	304	2.53
10/24/1998	297	2.27	11/20/2000	310	4.32

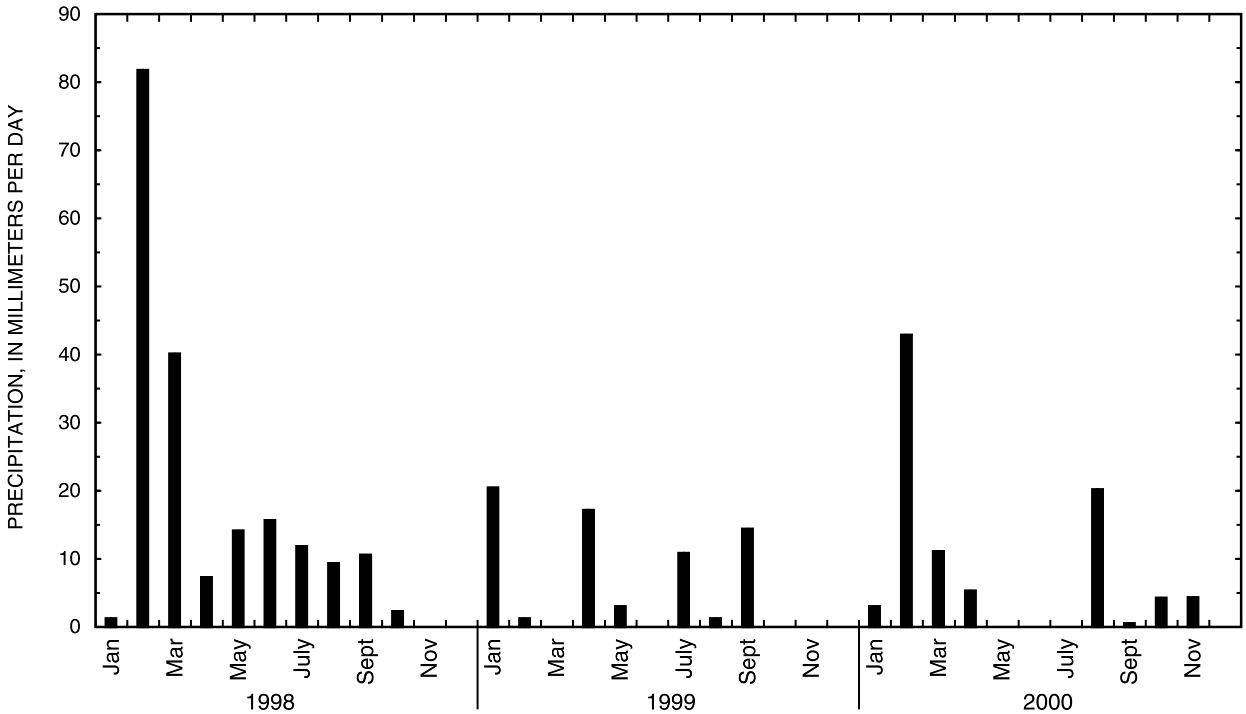

Figure 4. Monthly total precipitation at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals of daily totals.

cal low-pressure systems off the west coast of Mexico or southern California. Previous comparisons between the ADRS weather station and two National Oceanic and Atmospheric Administration (NOAA) sites (Wood and Andraski, 1995, p. 15) indicate monthly values also differ considerably between sites within the Amargosa Desert.

Monthly total precipitation is highly variable from year to year for a given month, and from month to month in a given year as shown in figure 4. For example, in 1998, January had little precipitation whereas February and March were wet. In 1999, January received considerable precipitation whereas February received little and March was dry. Then in 2000, January had little precipitation whereas February was wet and March was moderate. Other months also show monthly variability.

Air Temperature

Monthly maximum, minimum, and mean air temperatures are listed in table 2. Daily mean, maximum, and minimum air temperatures are listed in table 3 and shown in figure 5. Complete data for daily and hourly air temperatures are in appendix A (tables A1–A4). From 1998 through 2000 the maximum temperature recorded was 45.6°C in July of 1998 and the minimum temperature recorded was –14.1°C in December of 1998. During the 3-year period air temperatures averaged about 30°C during July and about 7°C during December.

Daily and seasonal temperature fluctuations are large at the study site. Differences between daily maximum and minimum temperatures commonly exceed 20°C. Differences between winter minimum and summer maximum temperatures average more than 50°C. The desert environment, with its high percentage of clear skies, has a large heating capacity from incoming solar (short-wave) radiation during the day, and a proportionally large heat discharge by terrestrial (long-wave) radiation during the night. The large gains and losses in energy on a daily basis and their relative variation on a seasonal basis determine the temperatures that occur in this environment.

Table 2. Monthly maximum, minimum, and mean air temperatures measured at Amargosa Desert Research site near Beatty, Nev., November 1998–December 2000

[Temperatures are in degrees Celsius. Maximum and minimum based on daily individual values determined from 8,640 samples per day (10-second sampling interval). Monthly mean obtained by averaging mean daily values]

Date	Maximum	Day	Minimum	Day	Mean
January 1998	19.3	24	-8.1	6	6.9
February 1998	17.6	22	-2.1	1	7.1
March 1998	28.2	23	-1.5	8	11.1
April 1998	30.5	22	-1.0	2	13.5
May 1998	30.5	31	4.3	13	17.3
June 1998	39.6	29	8.3	13	23.4
July 1998	45.6	18	14.8	4	30.8
August 1998	43.4	5	13.9	20	30.7
September 1998	37.9	3	9.0	29	23.9
October 1998	29.5	13	2.0	18	16.1
November 1998	22.9	23	-5.0	10	10.1
December 1998	24.1	16	-14.1	22	6.5
January 1999	21.4	10	-4.7	4	7.7
February 1999	22.7	28	-6.8	12	9.0
March 1999*	26.1	29	-2.6	8	12.4
April 1999	32.0	19	-2.7	10	13.5
May 1999	35.9	27	5.9	17	21.7
June 1999	42.5	30	8.6	3	26.7
July 1999	43.4	1	14.8	25	29.2
August 1999	40.0	26	15.0	11	28.7
September 1999	38.2	8	7.2	29	25.1
October 1999	35.7	1	1.9	31	19.0
November 1999	29.1	13	-6.3	23	12.2
December 1999	21.3	17	-5.8	4	7.4
January 2000	21.2	18	-7.4	29	7.8
February 2000	22.0	7	-1.5	24	9.4
March 2000	26.1	26	-1.3	7	12.5
April 2000	34.6	27	2.0	15	19.0
May 2000	40.5	29	6.2	12	24.6
June 2000	43.4	15	11.5	9	29.2
July 2000	43.6	4	16.0	9	30.6
August 2000	42.5	1	15.6	21	29.8
September 2000	39.9	16	6.0	25	24.7
October 2000	35.6	1	2.8	13	17.3
November 2000	22.4	24	-7.1	13	8.6
December 2000	21.6	28	-6.4	19	7.1

* 30 days of record.

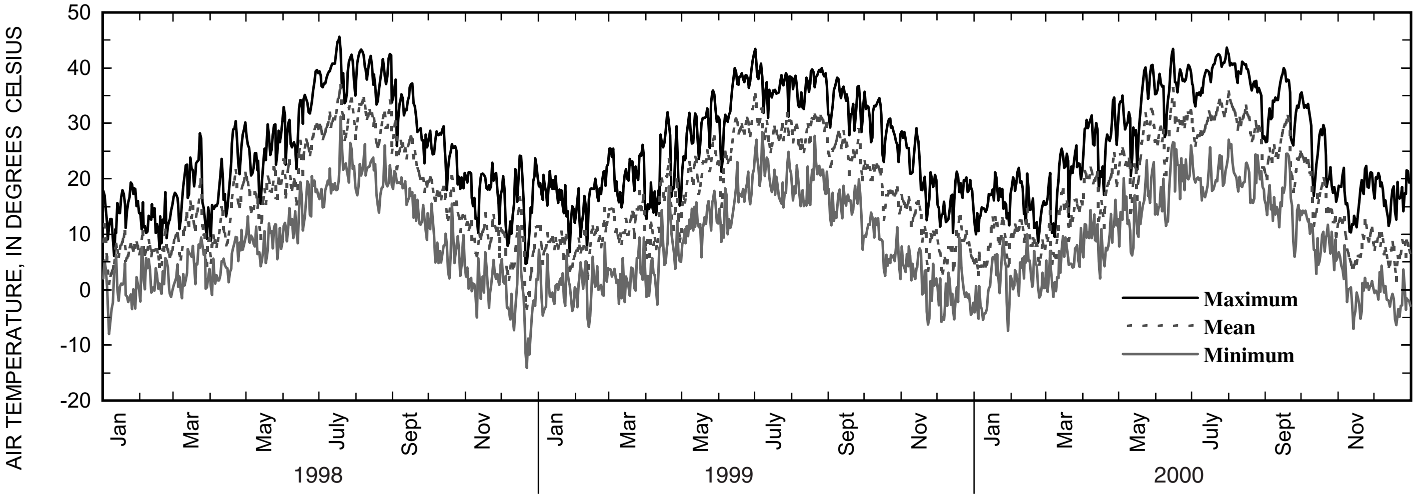

Figure 5. Daily maximum, minimum, and mean air temperature at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

Solar Radiation

Daily mean and maximum solar radiation are listed in table 3 and shown in figure 6. Complete daily and hourly solar-radiation data are in appendix A (tables A1–A4). Solar radiation is the amount of incident radiation from the sun that reaches the surface of the earth at the point of detection. Both daily and hourly mean and maximum solar-radiation data in this report are based on a 10-second sampling interval. Previous ADRS publications (Wood and Fischer, 1991, 1992; Wood and others, 1992; Wood and Andraski, 1992, 1995; Wood, 1996) also reported hourly mean and maximum solar radiation based on a 10-second sampling interval, but reported daily mean and maximum solar radiation derived from hourly mean values.

The daily maximum and mean solar-radiation curves (fig. 6) show the annual solar-energy cycle and the difference between the daily maximum and mean for any given day in the year. The maximum radiation for the year occurs during the summer solstice period in late June during clear sky days with maximum daily values generally exceeding 1,020 W/m^2. Conversely, during the winter solstice period in late December during clear sky days maximum daily values generally decrease to about 520 W/m^2. The downward spikes in figure 6 show the limited number of days where extended periods of cloud cover occurred during the day. As indicated in figure 6, the difference between the daily maximum and daily mean time-series values varies from over 750 W/m^2 in the summer to a minimum of about 370 W/m^2 in the winter.

Net Radiation

Daily mean, maximum, and minimum net radiation are listed in table 4. Daily values were based on hourly mean values. Complete daily and hourly net-radiation data are in appendix A (tables A1–A4). Net radiation is the difference between all downward and upward radiation fluxes of both short- and long-wave radiation. Net radiation is a measure of the energy available at the surface of the Earth that can be partitioned into such energy-consuming processes as heating the soil and air, plant growth, and water evaporation. By convention, net radiation is defined as positive when downward components (incoming radiation) exceed upward components (outgoing radiation), and this occurs after sunrise and before sunset. Allocation of this net available energy varies with seasonal surface conditions. For example, in late spring after a rainstorm, more energy is used to evaporate water from wet soils and for plant photosynthesis than is used to heat the air and soil. Later in the summer under dry conditions almost all of the available energy goes to heat the air and soil.

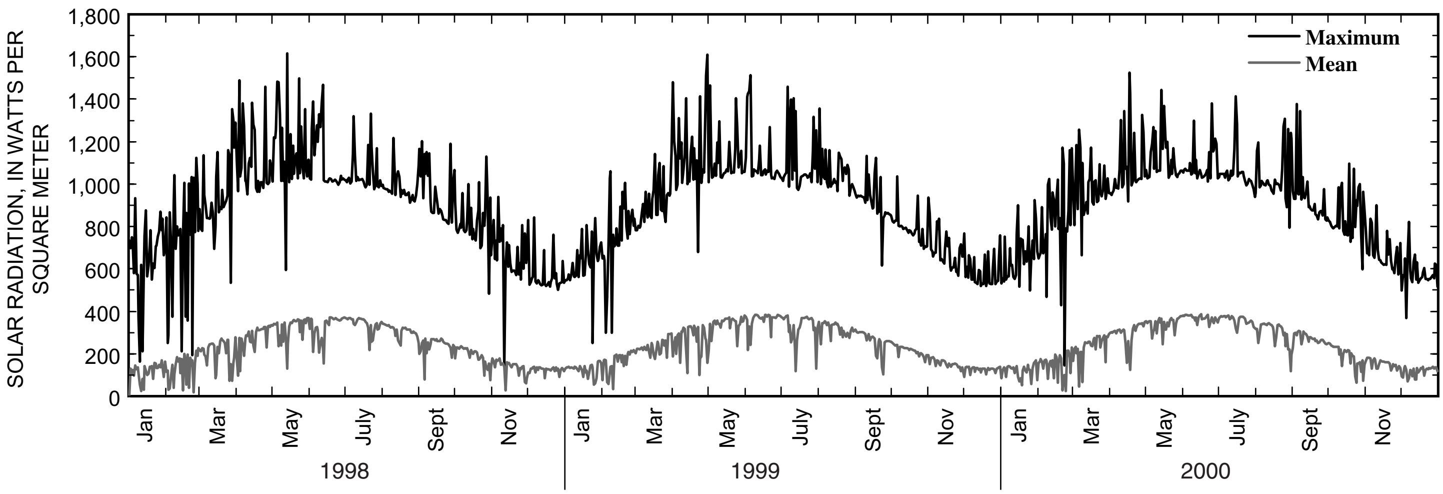

Figure 6. Daily maximum and mean solar radiation at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

Daily maximum and daily mean net-radiation curves are shown in figure 7. During a 3-year period (1998–2000), the 24-hour daily mean value generally fluctuated from 0 W/m^2 in early winter to about 150 W/m^2 in mid-summer. The daily maximum fluctuated from a low of about 250 W/m^2 in early winter to a high of about 550 W/m^2 in mid-summer. The mean net radiation that occurs from 8 a.m. to 4 p.m. PST also is shown to illustrate that a large part of daily net radiation available to the site occurs during the 4 hours before and after the near-solar noon. This daily 8 a.m. to 4 p.m. mean radiation is within 100 W/m^2 of the daily maximum radiation.

Relative Humidity

Daily mean, maximum, and minimum relative humility are listed in table 3. Daily mean relative-humidity values are shown in figure 8. Complete daily and hourly relative-humidity data are in appendix A (tables A1–A4). Relative humidity is the ratio of the amount of water vapor in the air at a specific temperature to the maximum amount of water vapor that the air can hold at that temperature and is expressed as a percent. Daily mean values ranged from 4 to 96 percent. In contrast, hourly mean values ranged from 1 percent during the drier summer months to 100 percent during winter storms. During mid-day hours in the summer, relative-humidity values of less than 10 percent are common in the Amargosa Desert.

Ambient Vapor Pressure

Daily mean, maximum, and minimum ambient vapor pressures are listed in table 3. Daily mean vapor pressures are shown in figure 9. Complete daily and hourly data are in appendix A (tables A1–A4). Ambient vapor pressure is the partial pressure exerted by water vapor present in the air and it indicates the water-vapor content of the air under prevailing atmospheric conditions. The ambient vapor pressure is the product of the saturated vapor pressure and the relative humidity. Saturated vapor pressure is the highest concentration of water vapor that can exist in equilibrium over a free-water surface at that temperature. The data logger calculates the saturated vapor pressure in kilopascals from measured air temperature using an algorithm from Lowe (1977).

Ambient vapor pressures generally are higher during the summer months and lower during winter months (fig. 9) because warm air can hold considerably more water mass than cold air. For this reason, the summer precipitation events cause high ambient vapor pressures, but larger winter precipitation events do not have comparable pressures (fig. 9). In 1998, daily mean values ranged from 2.1 kPa on September 4 after an evening rain to 0.089 kPa on December 19. For the 3 years of record (1998–2000), the maximum logged vapor pressure was 2.59 kPa on July 21, 1998, and the minimum was 0.048 kPa on May 14, 2000.

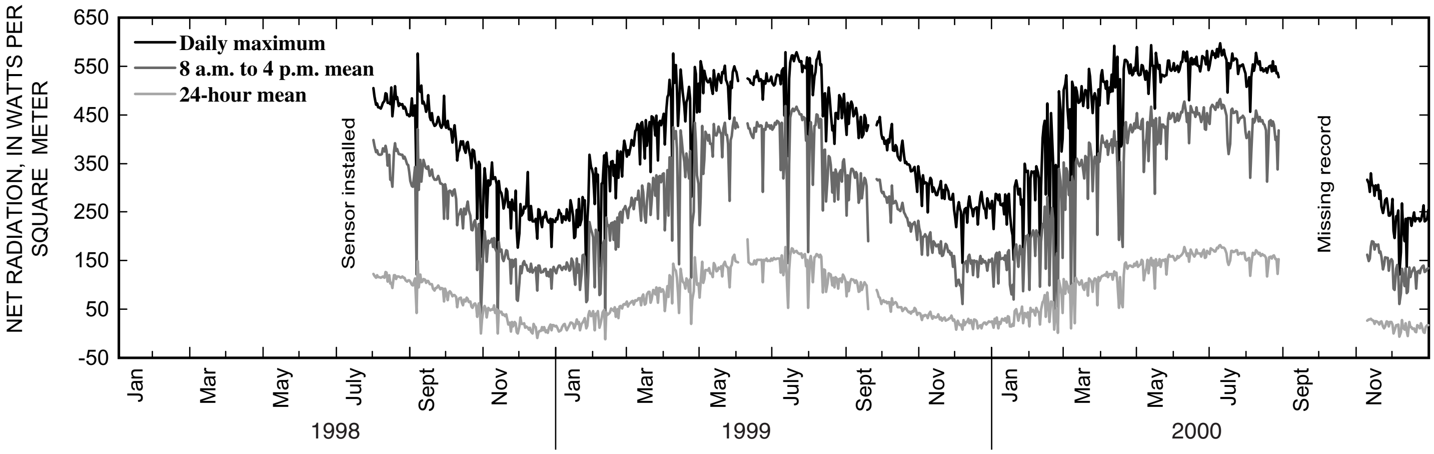

Figure 7. Daily maximum, mean, and mean from 8 a.m. to 4 p.m. of net radiation at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

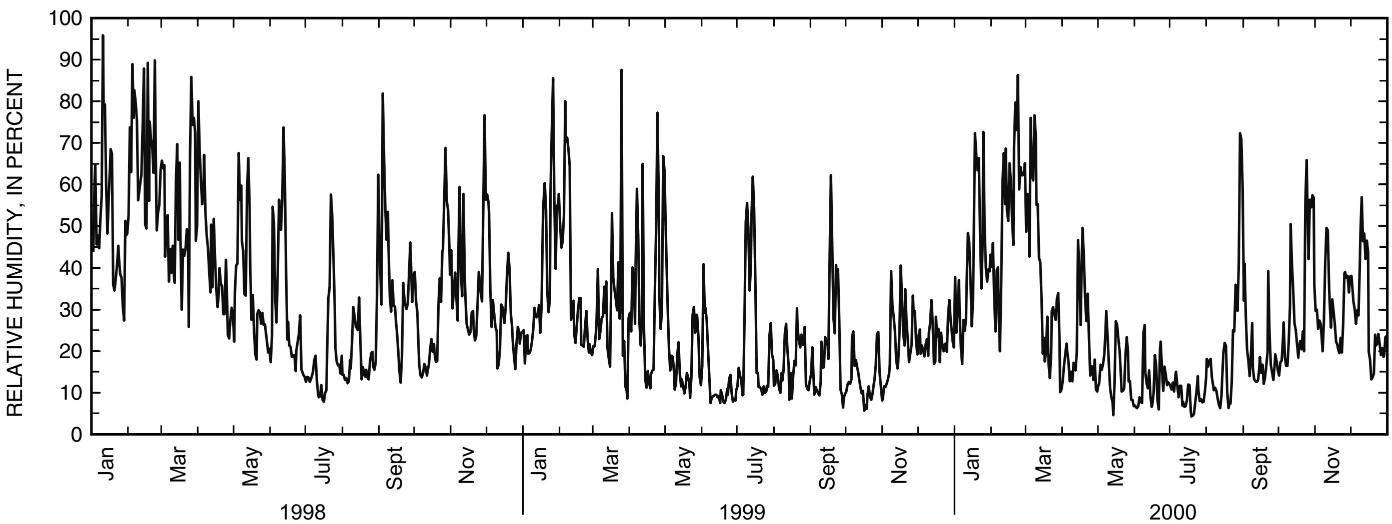

Figure 8. Daily mean relative humidity at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

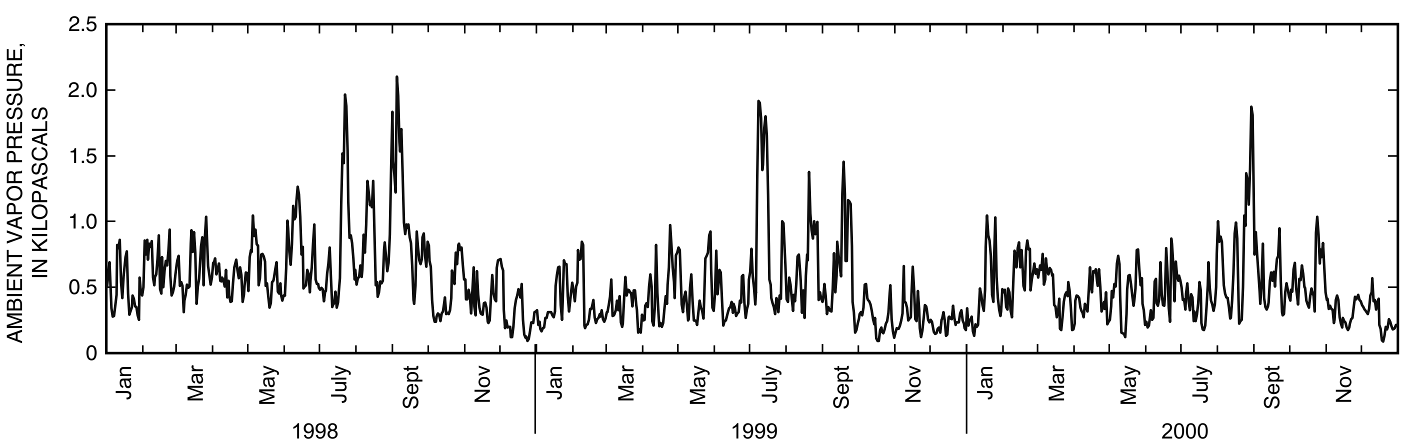

Figure 9. Daily mean ambient vapor pressure at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

Wind Speed and Direction

Daily mean, maximum, and minimum wind speed are listed in table 3. Daily mean wind speeds are shown in figure 10. Complete daily and hourly wind speed data are in appendix A (tables A1–A4). Annual mean wind speed computed from daily mean wind speeds (1998–2000) was 2.8, 2.8, and 2.9 m/s, respectively. During the 3-year period, the maximum, daily mean wind speed was 9.2 m/s on March 20, 2000 (fig. 10). The maximum, hourly mean wind speed was 13.0 m/s and occurred at 12 a.m. (midnight) PST on December 2, 1999. The single-highest recorded wind speed was 19.1 m/s on December 2, 1999. The distribution of hourly mean wind speed for the 3-year monitoring period for all values is shown in figure 11. For example, 4 percent of the time the wind speed was below 1.0 m/s, and 80 percent of the time the wind speed was under 4.0 m/s. Hourly mean wind speeds of 0.0 m/s occurred only 1.6 percent of the time during the 3 years of record. However, most days had at least one 10-second sampling interval with wind speeds below instrument threshold giving most days a daily minimum of 0.0 m/s.

Daily mean and standard deviation of wind-vector direction, in degrees Azimuth of true north, are listed in table 3. Complete daily and hourly wind-vector data are in appendix A (tables A1–A4). Mean horizontal wind-vector direction was calculated by vectorially summing the individual wind vectors consisting of wind magnitude and direction using available data logger commands. The daily mean wind-vector directions are shown in figure 12. Daily wind directions indicate seasonal variability and annual recurrent patterns for 1998–2000. Wind at the ADRS predominantly was from the northwest from September through February, and generally associated with regional frontal systems moving in from the west coast during the autumn and winter seasons. Winds from March to September are more evenly distributed from the northwest, southwest, and southeast. Southwest and southeast winds typically are associated with the counter-clockwise rotation of subtropical lows moving inland from off the west coast of Mexico or southern California.

Barometric Pressure

Daily mean, maximum, and minimum barometric pressures are listed in table 5. Complete daily and hourly barometric pressure data are in appendix A (tables A1–A4). Barometric pressures at the ADRS facility are corrected to sea level using an altitude of 847.2 m. Daily mean barometric-pressure values are shown in figure 13. The mean barometric pressure for the 3-year period (1998–2000) was 101.5 kPa. Higher pressures generally occurred during clear winter days and lower pressures occurred during storm periods and summer. The daily maximum barometric pressure measured was 103.57 kPa on December 18, 2000, and the minimum was 99.47 kPa on February 3, 1998.

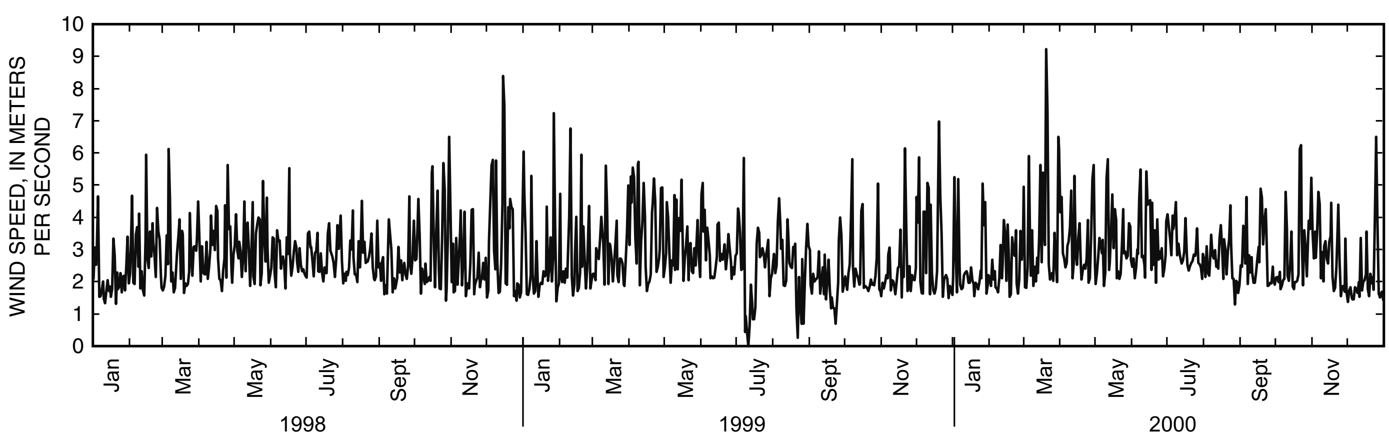

Figure 10. Daily mean wind speed at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

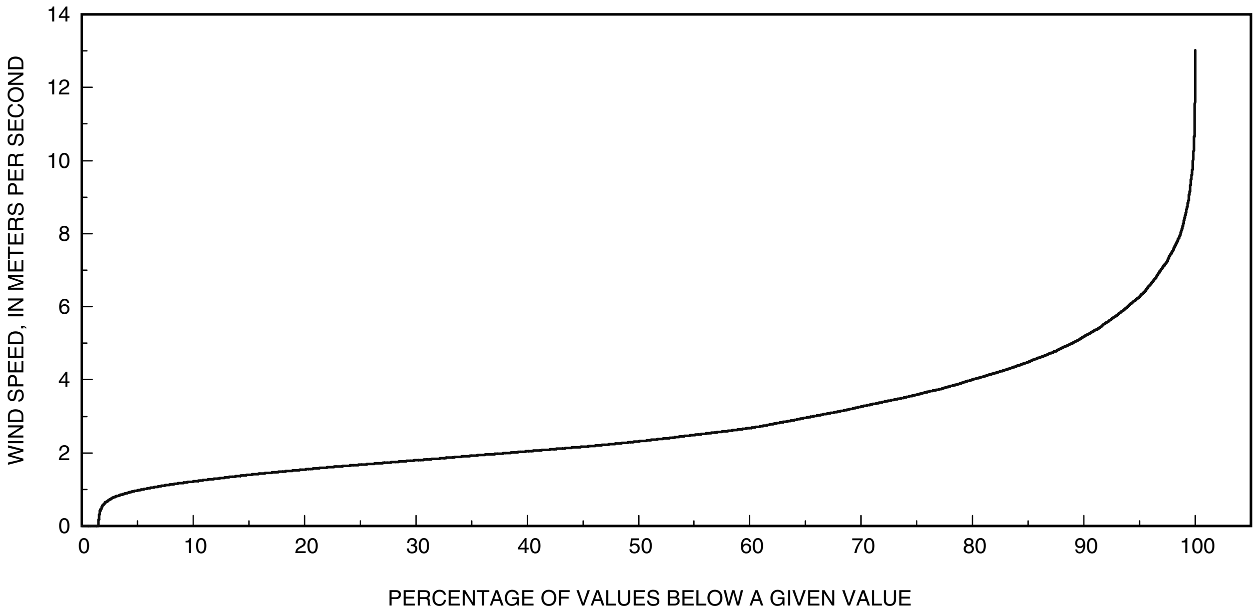

Figure 11. Distribution of hourly mean wind speed as a percentage of all hourly mean values at Amargosa Desert Research Site near Beatty, Nev., 1998–2000.

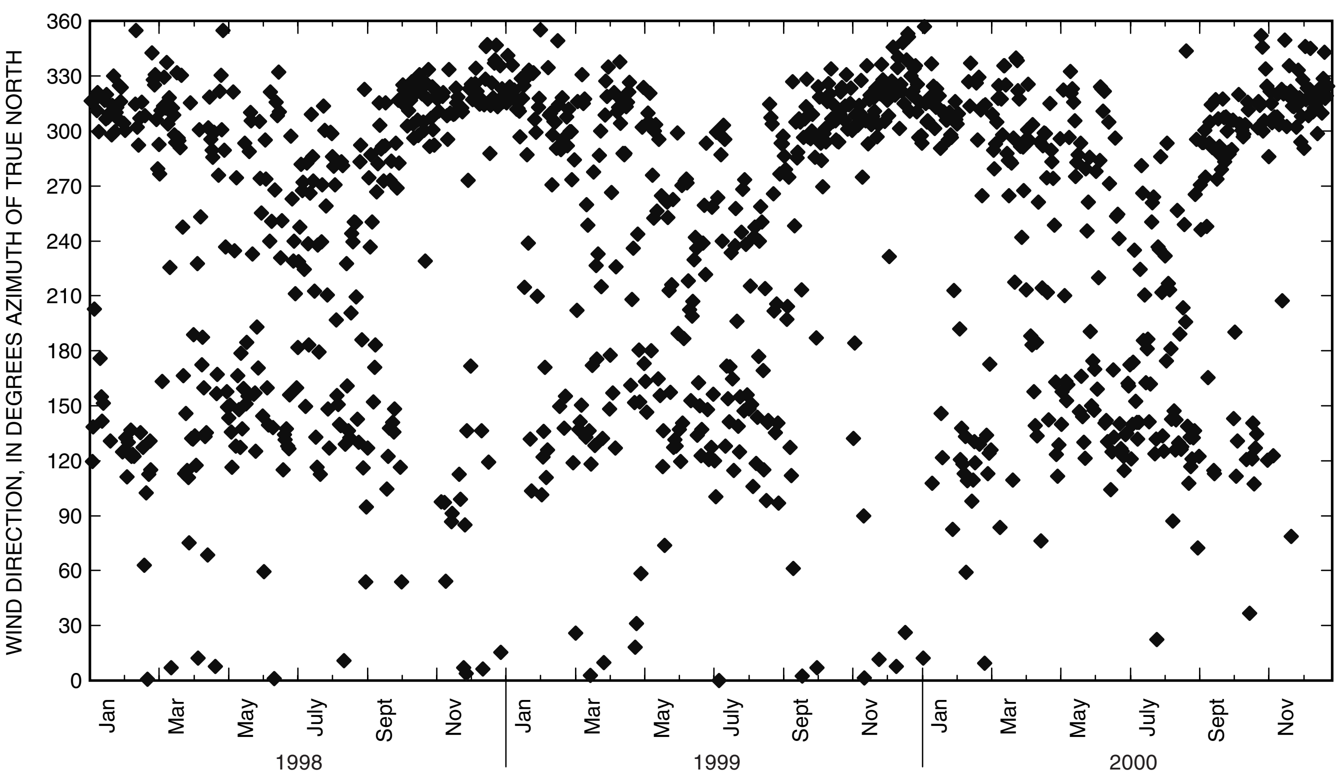

Figure 12. Daily mean wind-vector direction in degrees Azimuth of true north at Amargosa Desert Research Site near Beatty, Nev., 1998–2000.

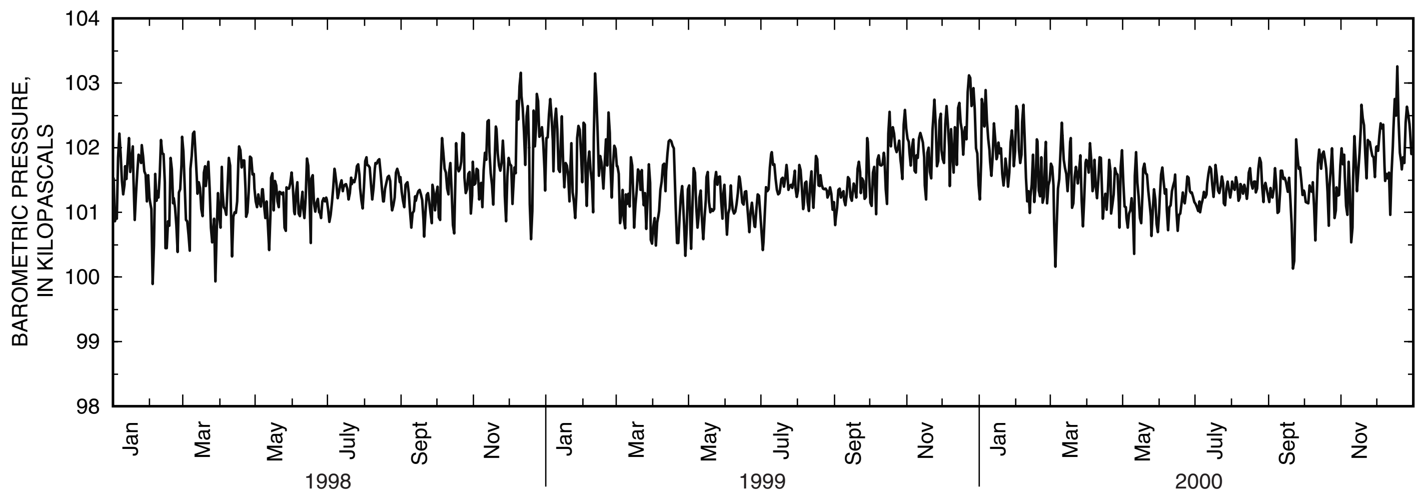

Figure 13. Daily mean barometric pressure at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

Soil Temperature and Soil-Heat Flux

Daily mean, maximum, and minimum values of soil temperature and soil-heat flux are listed in table 4. Daily soil temperatures and soil-heat flux are shown in figures 14 and 15, respectively. Complete soil temperature and soil-heat-flux data are in appendix A (tables A1–A4). The averaging soil-thermocouple probe measures the temperature in the soil between the 8-cm depth and the soil surface. The soil-heat-flux plates measure long-wave radiation in Watts per square meter that enters or leaves the soil. Soil-heat flux entering the soil is defined as positive and leaving the soil as negative. Daily mean soil temperature ranged from 2.6°C on December 19, 2000, to 40.9°C on August 1, 2000. Daily mean values of soil-heat flux ranged from –19.7 W/m^2 on March 5, 2000, to 15.8 W/m^2 on May 23, 2000.

SELECTED SOIL-MOISTURE DATA

Soil-water content under natural-site and simulated waste-trench conditions was monitored at four experimental sites: one vegetated, native-soil profile, one devegetated native-soil profile, and two non-vegetated, simulated waste trenches with disturbed soil used as back fill (figs. 2 and 3). The simulated waste trenches have 208-L soil-filled drums buried at depths from 1.5 to 2.5 m and 3.5 to 4.5 m; soil-water content is not determined for these depths because of the influence of simulated waste on neutron-probe readings. Soil-water content is reported in volumetric units of cubic meter per cubic meter.

Water-Content Profiles

Variations in volumetric water content measured in the deepest access tube at the vegetated, native-soil profile (tube VS2, 29.75 m) are shown in figure 16. Variations in water content in the upper 5.5 m for the four experimental sites are shown in figure 17. The changes in water content with time at selected depths for the four experimental sites are shown in figure 18. Complete soil-water-content data and the associated calibration equations are in appendix C (tables C1–C2). Table C1 lists the mean water-content data by date and depth for each of the four experimental sites. Table C2 lists the water-content data by date and depth for each of the nine neutron-probe access tubes.

Figure 16 shows the variability of water content with depth in the vegetated, native-soil profile. The water content within the upper meter of the soil profile ranged from a low of about 0.02 m^3/m^3 at the shallowest monitored depth of 0.15 m on August 3, 2000, to a high of about 0.12 m^3/m^3 at a depth of 0.5 m on March 15, 1998. The highest water content within the entire soil profile of about 0.15 m^3/m^3 was measured at a depth of 25.25 m for all dates measured. Temporal changes in water content are limited to the upper 1 m, whereas below 1 m the variation in depth reflects

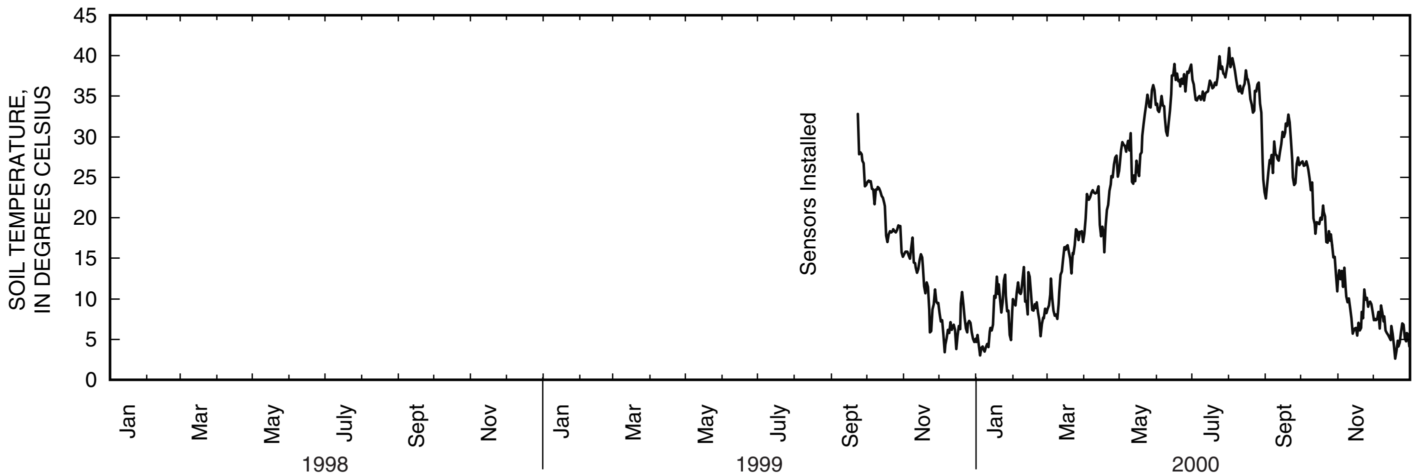

Figure 14. Daily mean soil temperature at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

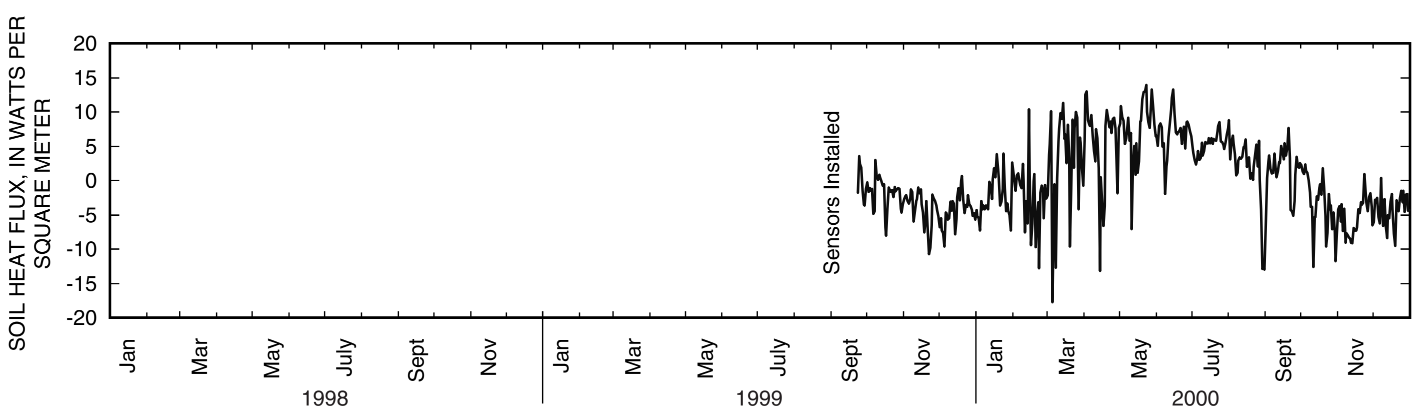

Figure 15. Daily mean soil-heat flux at Amargosa Desert Research Site near Beatty, Nev., 1998–2000, computed from 10-second sampling intervals.

changes in lithology and not time. At depth, moisture retention appears to be principally a function of grain size within the varying basin fill. Clay lenses within the sediments tend to have higher water content, whereas gravel layers have lower water content.

Figure 17 shows the temporal variation in soil-profile moisture in the upper 5.5 m. In the upper 1 m of the soil profile, the spring soil-water contents tend to be greater than late summer or autumn values. These variations can be accounted for by the redistribution of the soil-water with time and by increased soil-water discharge by evapotranspiration during summer.

Temporal variations in soil-water content for selected depths in the upper 3 m are shown in figure 18. All four experimental sites show measurable water penetration in response to precipitation at depths above 1.0 m (fig. 18*E*). The east trench shows measurable water penetration to a depth of 1.25 m (fig. 18*F*) peaking about May 5, 1998. That increase in water content at 1.25 m occurred in response to a series of late winter and spring storms that produced a total of 122 mm of precipitation during February and March 1998 and is associated with the latter part of an El Niño cycle. At the 3 m depth (fig, 18*G*), no measurable variation in water content exists at the four experimental sites.

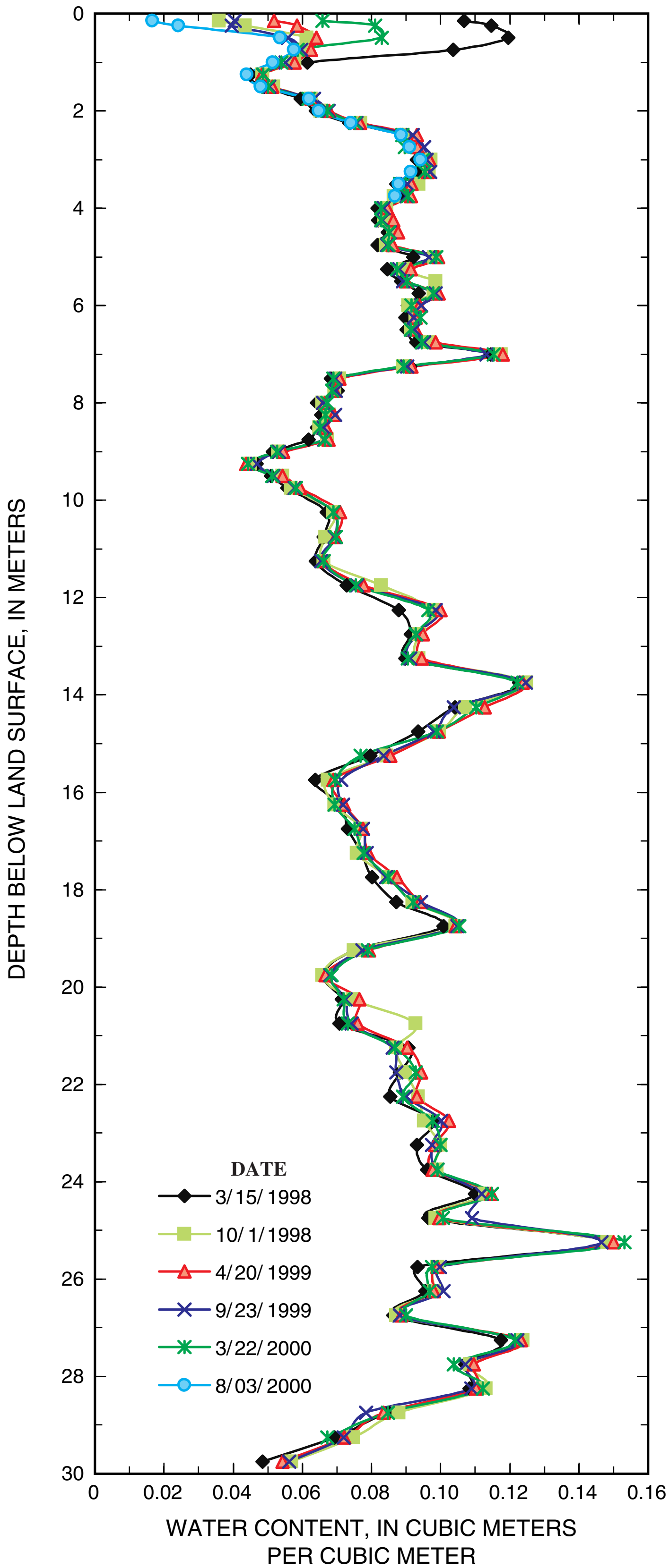

Figure 16. Water-content variations in the upper 30 meters for selected dates for the vegetated, native soil profile at Amargosa Desert Research Site near Beatty, Nev., 1998–2000.

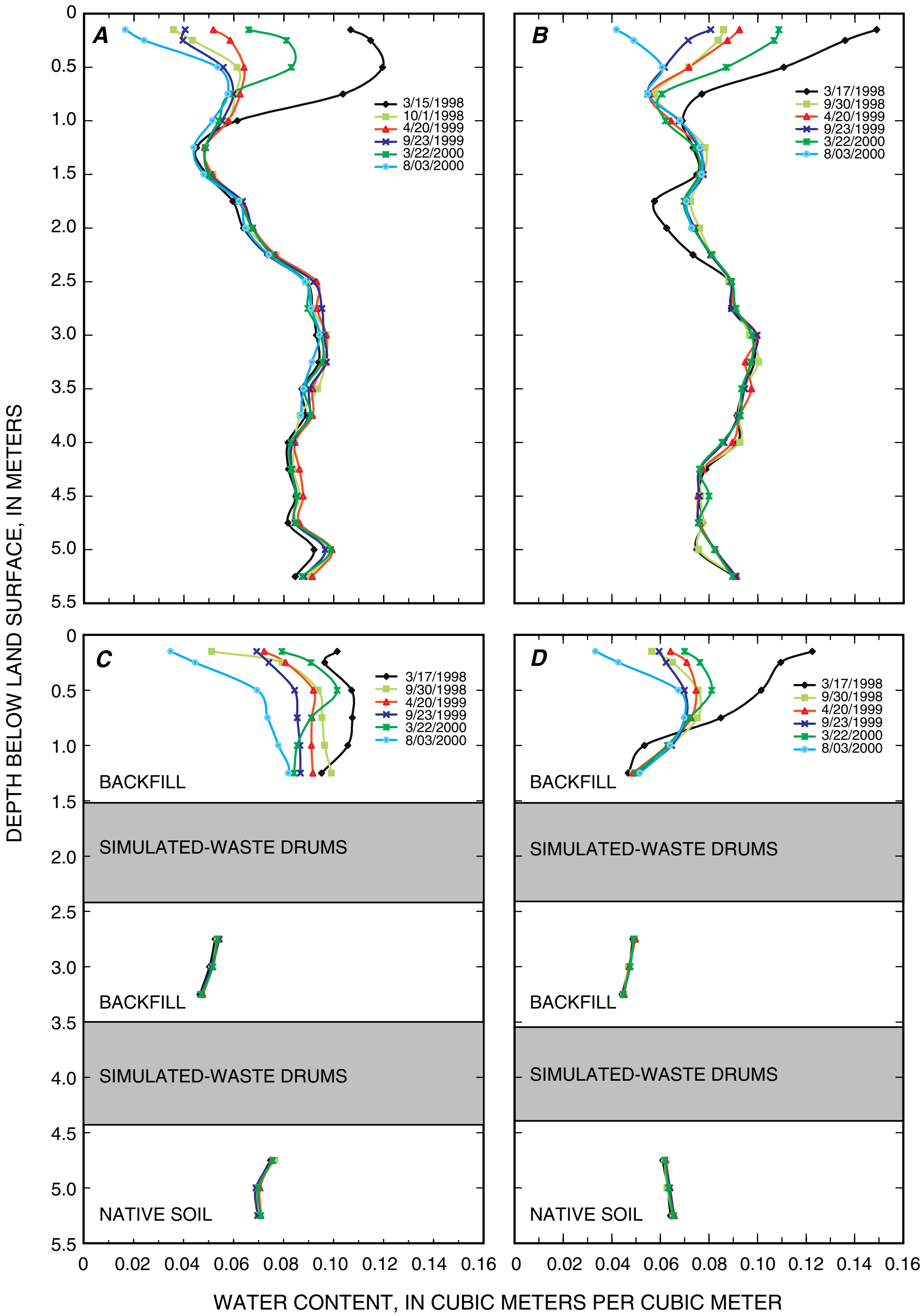

Figure 17. Water-content variations with depth in upper 5.5 meters of soil for selected dates at four experimental sites at Amargosa Desert Research Site near Beatty, Nev.: (*A*) vegetated, native-soil profile, (*B*) devegetated, native-soil profile, (*C*) non-vegetated, east trench, and (*D*) non-vegetated, west trench.

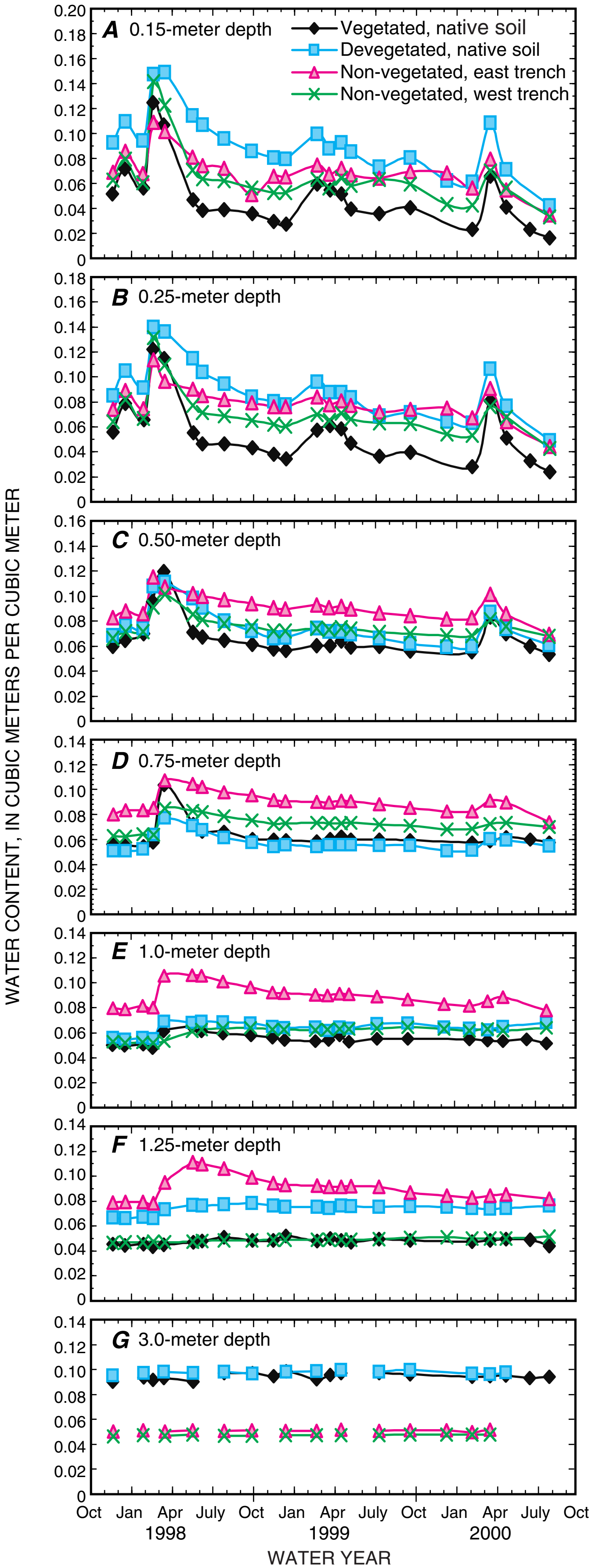

Figure 18. Cumulative changes in water content with time for selected depths at four experimental sites at Amargosa Desert Research Site near Beatty, Nev.: (A) 0.15-meter depth, (*B*) 0.25-meter depth, (*C*) 0.5-meter depth, (*D*) 0.75-meter depth, (*E*) 1.0-meter depth, (*F*) 1.25-meter depth, and (*G*) 3.0-meter depth.

SUMMARY

Micrometeorological and soil-moisture data were collected at the Amargosa Desert Research Site facility adjacent to a low-level radioactive and hazardous-chemical waste facility near Beatty, Nev. (1998–2000). Data were collected in support of ongoing research studies to improve the understanding of hydrologic and contaminant-transport processes in arid environments.

Micrometeorological data include precipitation, air temperature, solar radiation, net radiation, relative humidity, ambient vapor pressure, wind speed and direction, barometric pressure, soil temperature, and soil-heat flux. All micrometeorological data were collected using a 10-second sampling interval by data loggers that output daily mean, maximum, and minimum values, and hourly mean values. For precipitation, data output included daily totals, hourly totals, and 5-minute totals. Soil-moisture data include periodic measurements of soil-water content at nine neutron-probe access tubes with measurable depths ranging from 5.25 to 29.75 m.

Complete micrometeorological and soil-moisture data summarized in this report are in computer data files consisting of seven tabular files with about 14 megabytes of information. The data contained in the data files are summarized in figures and tables, and the instrumentation used for data collection is discussed. Data collection in 1998 occurred during the end of an El Niño cycle with above normal precipitation and measurable water penetration to a depth of 1.25 m at one of the four experimental soil-monitoring sites.

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BASIC DATA

This section contains tables 3-5, which summarizes selected micrometeorological data collected at the ADRS facility for 1998, 1999, and 2000. Table 3 lists daily mean, maximum, and minimum values of air temperature, solar radiation, relative humidity, ambient vapor pressure, wind speed and wind vector direction. Table 4 lists daily mean, maximum, and minimum values of soil temperature and soil-heat flux starting in September 1999, and net radiation starting in July 1998. Table 5 lists daily mean, maximum, and minimum barometric pressure.

For a complete listing of field data sets containing the meteorological and soil-moisture data, refer to the computer data files included with this report. The computer data files contain seven files with about14 megabytes of information in tabular format consisting of five different computer-data tables. The field data sets include: (1) one file (data table A1) listing daily mean, maximum, and minimum micrometeorological data and daily total precipitation; (2) three files (data tables A2, A3, and A4) listing hourly mean micrometeorological data and hourly precipitation for each year (1998-2000); (3) one file (data table B1) listing 5-minute precipitation data; (4) one file (data table C1) with four worksheets listing soil-water content by date and depth at four experimental sites; and (5) one file (data table C2) with nine worksheets listing soil-water content by date and depth for each neutron-probe access tube.

Table 3 (Microsoft Excel File, 902K)

Table 4 (Microsoft Excel File, 419K)

Table 5 (Microsoft Excel File, 76K)